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NASA/DoD Aerospace Knowledge Diffusion Research Project

AIAA-93-0580

P-16

Paper Twenty Four

*A General Approach to Measuring the Value of
Aerospace Information Products and Services*

*Paper Presented at the 31st Aerospace Sciences Meeting & Exhibits
of the American Institute of Aeronautics and Astronautics (AIAA)*

Bally's Grand Hotel

Reno, Nevada

January 13, 1993

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January 1993

N94-33371

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(NASA-TM-109775) NASA/DOO
AEROSPACE KNOWLEDGE DIFFUSION
RESEARCH PROJECT. PAPER 24: A
GENERAL APPROACH TO MEASURING THE
VALUE OF AEROSPACE INFORMATION
PRODUCTS AND SERVICES (NASA-
Langley Research Center)



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A GENERAL APPROACH TO MEASURING THE VALUE OF AEROSPACE INFORMATION PRODUCTS AND SERVICES

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ABSTRACT

This paper discusses the various approaches to measuring the value of information, first defining the meanings of information, economics of information, and value. It concludes that no general model of measuring the value of information is possible and that the usual approaches, such as cost/benefit equations, have very limited applications. It also concludes that in specific contexts with given goals for newly developed products and services or newly acquired information, there is a basis for its objective valuation. The axioms and inputs for such a model are described and directions for further verification and analysis are proposed.

INTRODUCTION

In trying to solve the riddle, "What is the value of information?" we are not sure whether it's as useless an exercise as counting the number of angels dancing on the head of a pin or an endeavor that ultimately will be as successful as the discovery of the Rosetta Stone.

From Stigler's, Machlup's and Shannon's early works 'till now - a period of some forty years - the messages and signals concerning the value of information have

been confounding, conflicting, and complex. Indeed, to some scholars, the conclusion often reached in frustration, not intellectual insight, is that it is futile to attempt to measure the value of information at all.

Nevertheless the effort goes on. Why?

To economists, information is the lubricant that makes a free market function. Since the essence of economics is the allocation of resources, and since it is the science that addresses uncertainty, information must be at its heart. Moreover, it is the information - who has it, when and where - that determines exchanges and prices of goods and services. It is at the core of equilibrium theory and a fundamental building block of decision theory. And as with other resources, its scarcity or restricted availability can add to its worth. In some cases, control of it makes it invaluable. We call this "Boesky's law of information."

Furthermore, the knowledge base of society has an impact on its economic development and standard of living, especially with the explosion of that base. From a lubricant and a market mechanism, information is now viewed as the engine of change in the post-industrial era. No wonder economists embrace it within their theoretical constructs.

Information scientists' interest in the economics of information has different roots. First and foremost has been the need to demonstrate that governments and organizations should invest in the

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development and dissemination of information because of its benefits to science and technology, to education, to mission oriented projects, and to society at large. Since budgets are in money terms, the cost of maintaining a library or building a database, for example, must be justified - again in money terms - by the benefits that will accrue. As we shall discuss later, therein lies the rub.

We recognize this must seem like an indictment of the process or as a self serving motive for undertaking the many studies of the value of information. Not at all. It addresses reality.

But beyond that there is a genuine desire and need to develop measures of value because of the absolute requirement to make hard decisions concerning the options and alternatives in creating, sharing, and applying information. Like other economic goods and services, trade-offs must be made among alternatives and to the extent one can approach a more optimum allocation of resources for information development, and use, the effort is worthwhile.

SEARCH FOR A THEORY

It's necessary, however, to distinguish between the ability to measure the value of information in specific cases versus developing a general theory of the value of information. After reading the literature and studying many of the principal empirical studies, we are convinced that developing a general theory of the value of information is highly unlikely if not impossible. On the other hand, measuring the contribution of information, and therefore its value, as the coalescing resource in asset creation or the accomplishment of specific missions is eminently doable. Why do we say that the development of a general theory of the value of information is highly unlikely? We can cite six good reasons:

First, the characteristics of information distinguish it from other so-called commodities or resources.

We are all too familiar with the recitation of these characteristics, but to summarize:

- Information is not depleted with use. It is even argued that information is expandable, that is, the more we use it the more profitable and valuable it becomes.
- Information is sharable. Unlike other goods, when information is sold or given away, the seller or giver still retains what has been sold or given away.
- Information, per se, has no intrinsic value. Unlike a sweater that gives warmth or an automobile that provides transportation, information is not wanted for its own sake.

Second, it is often difficult to distinguish between the information as content and the medium that delivers the message.

Increasingly, the information content is delivered seamlessly to the user. From their perspective, technology and content are inseparable.

Third, separating the flow of new information from the existing stock of information, often referred to as the knowledge base, is complex and often impossible. This is particularly troublesome as we evaluate libraries and information centers.

Fourth, in many cases, we are uncertain of the contexts in which the information is used or is going to be used.

Turning once again to our analogy of the sweater and the automobile, we know with very little uncertainty the context in which these products are used and the purposes for which they are produced and acquired. The same conclusions cannot be drawn about information.

Fifth, except for information products and services designed to be sold, most information lacks markets in which value can be determined by supply and demand.

A substantial percentage of information is developed for a specific purpose and never

enters or becomes part of a commercial transaction. Where such a transaction does take place, as in the case of a book or journal, a market price can be established. Even so, there are many questions raised, particularly by information specialists and librarians, concerning what they believe to be monopoly pricing, particularly in the scientific and technical areas.

Finally, it may be stated that the overwhelming importance of information is as a public good.

Information is the foundation for developing an aware and educated citizenry, addressing social problems, assessing investments in infrastructure and stimulating scientific and technical developments but the benefits are impossible to quantify or even to evaluate in the abstract.

Given these attributes and constructs, we cannot see information fitting into a single value model, no matter how complex that model may be.

Before turning to the alternative hypothesis - that in specific investments, applications and environments, the value of information can be determined in important and meaningful ways - it is essential that we define our terms and review the significant approaches to the subject, in order to provide a comfort level and, hopefully, acceptance of what follows.

WHAT IS INFORMATION?

We'll start with the term "information." It has become so generic that its use can be misleading or confusing. To some people, it means raw data, to others it quickly conjures up images of systems, and to still others it represents knowledge. Machlup defined it "as the act of informing, designed to produce a state of knowing in someone's mind." Others have defined it "as stored knowledge" or "data which is collected, processed, transformed, transferred, and made available."

I believe all would agree, with Horton, that the raw materials of information are data, documents, and literature. And, most students of the subject would also agree, more or less, that it is the organization and processing of these raw materials for the purpose of reducing uncertainty that constitutes information.

From the perspective of this study, we shall define information as content, the "intellectual stuff" that can be applied to solve a problem, reduce uncertainty and/or aid in decision making. Whether or not the package containing the content is referred to as a product is less important than the fact that it is the content of the package that is desired. We will distinguish this from the service that makes content available to users - libraries and information centers are the most significant - and we will reserve the term information technology for the tools that help collect, organize, manage and deliver the processed raw materials - the content - in a time, place and form, so that it can be applied to a particular problem.

THE SCOPE OF ECONOMICS OF INFORMATION

Information economics is a broad field of study.

In its most macro approach, it postulates that information is the driving force of an "information economy," defined as an economy in which the majority of employed persons are engaged in knowledge work. Porat's and Rubin's monumental works on the size and scope of the information economy is the outstanding example of this genre.

The information equivalent to welfare economics is the study of the contribution of information to the well-being of society. Many cost-benefit studies are of this variety.

Economics of information also addresses the impacts of information on organizations and work. Peter Drucker is the "oracle" of this school of thought.

On a more micro level, the economics of information embraces the processes by which information is produced, diffused, stored, and used.

Ultimately, as in traditional economics, the economics of information focuses on value - how it is determined, how it affects decisions concerning its creation and use, and how it provides the basis for the allocation of scarce resources.

DETERMINING VALUE

Which brings us to the question: what do we mean by value?

The concept of value springs from the classical economists' attempt to justify and rationalize the free market economy. Until then value was expressed in moral or physical terms. From a religious precept it was immoral to charge more than an ethical price, for example, or to establish usurious charges for money. From a physical perspective, there was intrinsic value; that is, a product or service was "good" or "valuable" because it delivered benefits, such as water for the thirsty, food, shelter.

And so, to avoid these moral-based assessments, and assuming perfect competition, fungible commodities and complete information, the measure of value was established as the price at the intersection of demand. This is the expression of the cumulative subjective wants and needs of consumers and suppliers and the willingness (or necessity) of producers to incur the costs necessary to bring the product to market.

Of course these assumptions - of a free market in which the goods are fungible, there are many buyers and sellers, and there is complete information - are abstractions.

Moreover, economists were faced with the "paradox of value." Why is water, so vital, so cheap? Why are diamonds, so frivolous, so expensive? In the end,

economists were forced to recognize that value has a human dimension that is largely subjective, and so they postulated two aspects of value: value in exchange and value in use, and chose to concentrate on exchange in the market place as the arbiter of value.

Value of information has all these problems and more. Since information is essential to reduce uncertainty and the degree of that uncertainty impacts value, how do we value the information itself? For example:

A plot of land is offered for sale. A willing buyer and seller have agreed on a price which to both represents the "value" of that piece of land. However, as a result of further investigation, it is discovered that at some previous time toxic materials were buried in that spot. Accordingly, the prospective buyer immediately reduces the offer or possibly completely withdraws from the transaction. The value of the land suddenly deteriorates or is wiped out.

What about the value of the information? In this case one might argue that the information was worth to the buyer, at most, the full amount of the savings from either not buying the land or buying it for much less than the asking price. To the seller, it may be worth the same but only if he could keep that information out of the hands of prospective buyers.

A second and often quoted example:

A woman's gold watch is stolen. She can buy information from a "source" that will enable her to locate the thief and retrieve the watch. What is the value of that information? The worth of the watch? Perhaps something more because of the sentimental value of that watch? Or perhaps less or nothing if she is fully covered by insurance?

But we can't stop there. Let's take the information developed in real time on the New York Stock Exchange. To traders that information is essential, or else they're out of business. It is mission critical and to get

it in real time is worth a high price. The information is immensely valuable.

For the analyst, who prepares reports at the end of a session, the information is necessary but does not have the same time or place utility. Therefore, the value of this identical information is less than that for the trader. A lag of minutes or even hours is perfectly acceptable - but at a discount.

Finally, for portfolio managers that same information, perhaps even condensed (Is this value added?) can be received days later. Their need suggests the willingness to pay a still lower price, hence reflecting the lesser value to them since time utility is less meaningful.

We can see then that value is not an absolute.

- Value is dynamic; it changes in time and space.
- Value is subjectively driven; it is in the psyche of the buyer and/or user.
- Value is mission sensitive; it changes with its criticality.
- Value is solution induced; it is derived from its context.

The literature on the "value of information" or, more broadly, "information economics" is extensive and a number of excellent reviews and critiques, as well as bibliographic references, have been published. Among these are works by Flowerdew and Whitehead, Martyn, King, Griffith, Rapo and Koenig. More recently, Mackenzie Owen authored a report on "Aspects of the Value of Information" for RABIN, the NCLIS of the Netherlands; there was an excellent summary and bibliography in English at the end of the report. Given these thorough overviews, it would be redundant to conduct one more excursion through the relevant literature.

Nevertheless, several aspects of these studies deserve comment because they can be misleading and possibly irrelevant.

The concept of the value of information is dichotomous. Here are a few examples:

Value of Content
Value of Delivery System
Value of Exchange
Value in Use
Practice Value
Imputed Value
Marginal or (added) Value
Total Value
Ex-ante (expected) Value
Ex-post (received) Value

While many of the theories and investigations into the "value of information" recognize these dichotomies, they are often slighted or ignored. Merging content and delivery is most typical, largely because the effort is directed to the value of the delivery service while content is a tag-along component. But, the core problem is what we'll call "definitional disorder," the absence of consensus on meaning and measurements. We'll start with costs.

WHEN IS A COST NOT A COST?

Costs incurred in developing and delivering any product or service are at the core of the supply curve. Producers incur costs when they believe they will have something to sell. Costs would seem to provide a quantitative and objective statement of the resources - labor, materials, capital, etc - which must be acquired to get the job done. Therefore, the determination of value, including that of information, has often been equated with or incorporated with costing. But which costs? Total costs, fixed costs, marginal costs, allocated costs? What about sunk costs, opportunity costs and, even more puzzling, cost avoidance? And, in which terms - original costs, replacement costs, or imputed costs? And if they are allocated costs, on what basis should the allocation be made - manpower, square footage, historical usage?

There are real problems with costing models that rely heavily on allocations or imputation. Too many cases can be cited where an inappropriate allocation of shared or joint costs resulted in completely wrong and expensive decisions.

Imputing costs to a facility or product can be much more misleading or dangerous. They especially have no meaning to decisions concerning current creation of or investments in information.

Opportunity costs as a concept, on the other hand, can be relevant when several options are being considered and the availability of funds is limited. The same conclusion holds for comparative measures of cost-effectiveness where there are alternative avenues for achieving the desired results and the task is to minimize costs. But even in these cases, costs must be direct costs with minimal allocations and no imputations. Most importantly, they must be related to the project or proposal at hand.

Cost avoidance, which seems to gain favor among those seeking to justify particular services, is a fallacious concept. For example, how much of the researcher's time was saved by using the information center, thus avoiding the cost of his or her time in seeking out the information. One astute critic defined cost avoidance this way "I do not spit on the sidewalk, I do not pay a twenty-five dollar fine. Therefore, I have avoided a cost of \$25."

The use of costs, then, in any measure of information's value must be explicitly defined and consistently applied, avoiding the injection of intuitive, arbitrary, or representative measures. We'll have more to say about this later.

THE PSYCHOLOGY OF BENEFITS

Benefits - the obverse of cost - have many of the same problems. Used as a surrogate for value either absolutely or after subtracting costs, they are rooted in expressions of psychological needs and wants on the one hand, and satisfactions and rewards on the

other. They are expressions of personal or group judgements of results. In either case, most benefits are imputed in dollar terms, and the identification and gratification of these benefits are as perceived to be appropriate by the researcher or the subject.

For example, in assessing the benefits of an Information center, the value of the time saved in searching for appropriate literature or reading the latest scientific paper is considered a benefit while the actual time spent is considered a cost. But this calculation is based on the loaded salary of the researcher. What if a lesser paid researcher - either in a less affluent environment or somewhat lower in the pecking order - had saved the same hours. Would the benefits be less? More importantly, what if it were the lower paid researcher who finally found the clue to a major technological or scientific breakthrough?

One way around that dilemma is to impute value by questionnaire, inquiring of researchers how the research led to results and what they were worth. This assumes that researchers know the full scope and later consequences of the indicated results and that they are quite objective about their assumptions and conclusions.

Even more questionable is the attempt to estimate the total benefits to society of given information efforts. On the basis of some of these estimates, it is hard to believe we have not been able to eliminate the federal deficit.

When President Kennedy, for reasons of national pride and national defense, set a target date for a moonlanding, he probably had been given estimates, undoubtedly too low, of the cost; the benefits he perceived, however, undoubtedly were beyond the realm of quantitative measurements, nor did it matter. But think of it. This triumph was a triumph of information and information technologies. What was the ultimate value of the miniaturization of computers that fit into the tiny spaceship and controlled its landing? And what about

the information that made possible the pinpoint guidance of that space vehicle? The fallout from the development program that made landing on the moon possible, in terms of the dramatic revolution in information creation and delivery, I submit, can never be measured.

Then there is the other question, what about all those saved hours that led to nought? The research into cold fusion, for example. And what about prior readings stored in human memory which recalled and connected with the most recent readings could cause the light of discovery to flash? How does one impute value to that process?

The fact is that we really do not know which publication or article triggered what thought that led to a particular breakthrough in science or technology, even if we can ascribe, after the fact, the out-of-pocket costs of doing the research. We cannot impute the value of the learning process and prior experiences, and it is very difficult to quantify the benefits beyond the immediate tangible applications of the fruits of that research.

Conclusion: one person's imputed value can be another's wasted time.

To put more objectivity into benefit imputations, the concept of willingness to pay has been introduced and well documented, for example, in actual experiments by King and Griffith. It assesses the probable value of a particular research effort as if it had been paid for - an attempt at simulating a market price. This willingness to pay concept presents two alternative scenarios: the equivalent salary of the researcher, signifying a willingness to "pay" for use of the facility and devote time to acquiring the appropriate knowledge; questionnaires that solicit the willingness to expend resources to acquire information.

Both these approaches have serious drawbacks. First, who is doing the paying - the researcher, the government, the company? Secondly, how would willingness to pay change if the source of

the funding changed - if the researchers themselves would be required to pay out of their own pockets? Third, is the indicated willingness to pay followed by actual payment? The first is subjective and judgmental; the second problematical; the third is objective and real.

Any seller of information knows that willingness to pay has meaning only when he or she gets paid. Publishers of information never believe verbal intent; they always ask for the order. That is the acid test.

VALUE IN USE

Willingness to pay and benefits of information in time savings have led to increased attention to the concept of value-in-use and draw on the "paradox of value" in economic theory.

Defined as the benefit the user obtains from the use of the information and the effect of its use, value-in-use relates to the search for, and acquisition of, information and the situation or environment in which it is used. Thus, there is a perceived or expected value in seeking the information, a value in reducing uncertainty through the use of the information, and value in the effect of the information or the end results. Taylor, among others, described this as a value-added process.

Some, like Repo, also believed that not unlike economics, there can be a measure of value-in exchange as well as value-in-use. This concept recognizes that there are information products that find their way into the market place or can be "priced at market" based on opportunity costs.

While these concepts move us closer to a solution to meaningful quantification of the value of information, they still leave too many holes in the equations, which must be filled with conjecture, estimations, and imputations. Moreover, they largely ignore the role of costs in value determination.

It is the ex-post characteristic of value-in-use that causes concern. It places value

after the fact and while that can possibly support or justify previous investments in information and the expected benefits of the use of that information, it does not provide guidance in decision making concerning the desirability of making those investments in the first place.

Nevertheless, while in many respects value-in-use depends heavily on imputation, not unlike cost-benefit models, it makes several important contributions to our search for an objective measurement of the value of information. It recognizes that valuation must be based on the context, environment, and purpose for which the information is desired; it adopts a marginal approach which avoids attempts at globalizing value or calculating value in part on cost avoidance or benefits foregone; it distinguishes between the content and the delivery system and, in some versions, also seeks to separate value-in-exchange and value-in-use.

RULES FOR VALUING INFORMATION

Where does all this lead? If the discussion thus far sounds negative, it is only because it is important to clear away some of the unworkable concepts and constructs in order to lay out an appropriate paradigm for future investigations of the value of aerospace information products and services.

Following are seven axioms we believe must guide any attempt to measure the "value of information".

1. Information and information services are distinct and must be valued separately.
2. Information's value is determined as a flow (value-added) at the margin. Valuing the stock of existing information - the knowledge base - is arbitrary and subject to personal and institutional bias.
3. "Value of information" cannot be measured in the absence of a specific task, objective or goal. Total value is not meaningful.

4. Costs should be measured incrementally. Inputted costs and sunk costs are inappropriate.

5. Demand for information is determined ex-ante and is subject to uncertainties inherent in all demand equations. It is expressed in the bid price(s) for the specific information.

6. An information service may be created or acquired as an investment. If so, it should be valued in the same manner as any other investment.

7. Value-in-use and cost/benefit models are ex-post. As such they are audits of performance rather than measures of value.

CONCLUSION

Based on these axioms, we can now propose a general approach to measuring the value of aerospace information products and services.

We distinguish between determining the value of a prospective new or add-on information product or service and auditing the performance of an existing information product or service. We make this distinction because the former requires establishing a money value in anticipation of a commitment to buy or invest, while the latter reflects realized benefits, many of which cannot and need not be measured in money terms. Thus, valuation is ex-ante while benefits are ex-post.

We submit that the most meaningful measure of the value of information is in anticipation of a new product, project, mission, task or investment because the information is a catalyst, a resource, a factor of production if you will, rather than the end product in its own right. In the aerospace industry and environment, the information is not desired for itself but rather in support of a mission, a new platform etc. It will be created only to the extent that it is believed to add value to that mission or platform. And that belief creates the true willingness to pay.

The model to establish this value is quite simple and clear cut.

1. The project, mission, or platform must be identified and its goals specified.
2. The expected contribution of information must be detailed and the potential owners of the information product or service identified.
3. The contribution in money terms of the information to the success of the project or platform must be projected. This becomes the bid price for the information.
4. The structure, components, and sources of the inputs for the proposed information product or service are particularized.
5. The marginal or incremental costs that would be incurred in developing the product or service are identified and measured.
6. From the cost estimates, an asking price is established.
7. "Buyer" and "seller" must then agree on a final price. To the extent "buyer" and "seller" do not agree, they must consider: (A) modification of the plan (e.g. alternative options) to reduce the asking price or (B) modification of the specifications to meet the buyer's requirements and willingness to pay (including possible reduction in scope, comprehensiveness, and timeliness).

Establishing the worthiness of an existing product or service requires a somewhat different model. There are two possible scenarios. One is to audit the results to establish whether or not the information product or service has achieved its stated objectives. In this instance, the costs incurred would be compared with the estimated cost and the actual contribution would be measured against the projected contribution. For such an audit, secondary and tertiary benefits may be taken into account since the fall-out beyond the initial expectations can be meaningful.

The second scenario concerns a review of the performance of a product, particularly an information service, in anticipation of funding (budgeting) either on an ongoing basis or for a change in size or scope. We consider this too to be an audit rather than an attempt at valuing the product or service and while many of the benefits (ex-post) can be identified, they may elude quantification except by imputation.

1. The mission of the facility must be clearly articulated and the methodology for measuring accomplishment of that mission must be established. These measures of performance need not be solely monetary.
2. Costs of operation should be calculated. Essentially these should be actual cost incurred in meeting a mission. Allocated costs for shared facilities or personnel should be based upon an objective measure of the distribution of those costs agreed to between those who share them. Sunk costs should be ignored. Imputed costs or measures of cost avoidance or benefits lost must be avoided.
3. An evaluation of whether the facility is fulfilling its mission must be made. It is recognized that this valuation is highly subjective and cannot be made by the individuals who are responsible for providing the service. It should be made by an independent "auditor" with inputs from those who are served by the facility. The performance must be compared against the factors identified as the measures of accomplishment of the facility's mission.
4. The costs should be related to accomplishments to determine whether the service is effectively meeting its objectives. This too is a subjective valuation and will lead to decisions whether and how the program should continue, or whether it is necessary to opt for alternatives.

To attempt any monetary or numeric equations for these in-place facilities may give a sense of objectivity but, in reality, it does not add to the ability to make appropriate decisions concerning the merits

of the program. Putting dollar signs to the amount, especially imputed dollars, would not create a statement of value.

For the future, therefore, we recommend two separate pilot studies: one for a new product or service and one for the audit of an existing service. These could establish the guiding principles and parameters, the basis for comparisons among alternatives, and, most important, a methodology to assist the uninitiated in participating in important decisions concerning investments in real dollars on aerospace information products and services.

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NASA/DoD AEROSPACE KNOWLEDGE DIFFUSION RESEARCH PROJECT

Fact Sheet

A research study is investigating the production, transfer, and use of scientific and technical information (STI) in aerospace, a community which is becoming more interdisciplinary in nature and more international in scope. Sponsored by NASA and the Department of Defense (DoD), the NASA/DoD Aerospace Knowledge Diffusion Research Project is being conducted by the Indiana University Center for Survey Research and the NASA Langley Research Center with the cooperation of the AGARD and AIAA technical information panels.

This 4-phase project will provide descriptive and analytical data regarding the flow of STI at the individual, organizational, national, and international levels. It will examine both the channels used to communicate STI and the social system of the aerospace knowledge diffusion process. The results of the Project should provide useful information to R&D managers, information managers, and others concerned with improving access to and utilization of STI. Phases 1 and 4 investigate the information-seeking habits and practices of U.S. and non-U.S. aerospace engineers and scientists and place particular emphasis on their use of government funded aerospace STI. Phase 2 examines the industry-government interface and places particular emphasis on the role of the information intermediary in the knowledge diffusion process. Phase 3 concerns the academic-government interface and places particular emphasis on the information intermediary-faculty-student interface.

Empirically, little is known about the production, transfer, and use of aerospace STI in general and about the information-seeking behavior of aerospace engineers and scientists in particular. Less is known about the effectiveness of information intermediaries and the role(s) they play in knowledge diffusion. It is generally assumed that information intermediaries play a significant role in the aerospace knowledge diffusion process. However, a strong methodological base for measuring or assessing their effectiveness is lacking.

The ability of aerospace engineers and scientists to identify, acquire, and utilize STI is of paramount importance to the efficiency of the R&D process. An understanding of the process by which aerospace STI is communicated through certain channels over time among members of the social system would contribute to increasing productivity, stimulating innovation, and improving and maintaining the professional competence of aerospace engineers and scientists.

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